

ASSESSMENT OF THE UTM CAR-FREE DAYS USING DISTANCE MEASUREMENT METHODS IN GIS

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A dissertation submitted in partial fulfillment of the requirements for the award of the
Degree of Master of Science (Geoinformatics)

Faculty of Geoinformation and Real Estate
Universiti Teknologi Malaysia

August 2017

This dissertation is dedicated to Mr. Ahmed Hassan, my beloved brother who is constant source of inspiration to me.

ACKNOWLEDGEMENT

All praises are due to ALLAH who helped me to accomplish this study. I would like to express my gratitude and give great thanks to my supervisor, Sr Dr. Shahabuddin Amerudin, MRISM for his encouragement and consistent support of my study. His guidance and invaluable advice helped me throughout the study.

My sincere appreciation also goes to UTM Campus Sustainability Unit, especially Assoc. Prof. Ir. Dr. Mohd Fadhil who contributed some brilliant ideas to the study. I would also like to thank my classmates who helped me to distribute the questionnaire among UTM campus community.

Finally, I would express a deep sense of gratitude to my parents for their constant love and prayers to succeed in my study as well as my brother and sisters for their encouragement and inspiration.

ABSTRACT

The UTM Car-Free Day is an initiative that is intended to reduce car-induced emissions, promote healthy lifestyle modes of transportation and improve environmental sustainability awareness among campus community. Currently, Car-Free Days assessment methods are not comprehensively studied, especially using GIS. Thus, it is needed to be used an appropriate technique for the assessment of the Car-Free Day initiative, in this respect, the study used distance measurement methods in GIS by measuring travel distances both during Car-Free Days and normal days and modelling travel patterns. In this study, online and paper-based questionnaires were designed and distributed to UTM campus community in order to obtain residential addresses, parking lots, modes of transportations and level of awareness towards the UTM Car-Free Day initiative. In total, 119 valid questionnaires were collected for the purpose of the study. Network datasets were built within a GIS database using ArcGIS Network Analyst Extension to perform shortest path analysis between the two centroids of residential addresses (origins) and parking lots (destinations). Moreover, nearly 22% of the respondents drew their actual travel routes and it is used on-screen manual digitizing to model and measure the actual travel routes of the respondents. The measured travel distances during Car-Free Days and normal days using shortest path and actual travel route measurements were compared using dependent *t*-test for paired samples and the tests for both methods were not significant. Furthermore, Pearson's Correlation test was conducted and the test revealed that there are significant strong positive correlations between actual travel route measurement and shortest path network. Therefore, the study proves that there are no different in travel distances during Car-Free Days and normal days, thus, the current UTM Car-Free Day initiative did not reduce travel distances on the campus. Results of this study could be mainly beneficial to the university's Car-Free Day initiative program. Finally, the study recommends suggestions that may improve the successfulness of the UTM Car-Free Day initiative and aspects that enhance the methodology of assessing the impact of the Car-Free Days on travel distances.

ABSTRAK

Hari Bebas Kenderaan UTM ialah inisiatif yang bertujuan untuk mengurangkan Pelepasan asap kenderaan, menggalakkan mod pengangkutan dengan gaya hidup sihat dan meningkatkan kesedaran kelestarian alam sekitar dalam kalangan komuniti kampus. Pada masa ini, kaedah penilaian Hari Bebas Kenderaan tidak dikaji secara menyeluruh, terutamanya dengan menggunakan GIS. Oleh sebab itu, teknik yang sesuai diperlukan untuk penilaian inisiatif Hari Bebas Kenderaan, iaitu dalam hal ini, kajian menggunakan kaedah pengukuran jarak dalam GIS untuk mengukur jarak perjalanan semasa Hari Bebas Kenderaan dan hari biasa dan memodelkan corak perjalanan. Dalam kajian ini, kaji selidik dalam talian dan berasaskan kertas direka bentuk dan diedarkan kepada komuniti kampus UTM untuk mendapatkan alamat kediaman, tempat letak kereta, mod pengangkutan dan tahap kesedaran terhadap inisiatif Hari Bebas Kenderaan UTM. Secara keseluruhan, 119 soal selidik telah dikumpulkan untuk tujuan kajian ini. Kajian ini membina set data rangkaian dalam pangkalan data GIS dengan menggunakan ArcGIS Network Analyst Extension untuk melakukan laluan analisis terpendek antara dua titik tengah alamat kediaman (asal) dan tempat letak kereta (destinasi). Tambahan lagi, hampir 22% responden melakarkan laluan perjalanan sebenar mereka dan ianya telah didigit secara manual pada skrin untuk memodelkan dan mengukur laluan perjalanan sebenar responden. Jarak perjalanan yang diukur semasa Hari Bebas Kenderaan dan hari-hari biasa dengan menggunakan laluan terpendek dan pengukuran laluan perjalanan sebenar dibandingkan dengan menggunakan ujian t bersandar untuk sampel berpasangan dan ujian untuk kedua-dua kaedah tidak ketara. Tambahan pula, ujian Korelasi Pearson dijalankan dan ujian menunjukkan terdapat korelasi positif yang kuat antara pengukuran laluan perjalanan sebenar dan rangkaian laluan terpendek. Oleh itu, kajian membuktikan bahawa tiada perbezaan dalam jarak perjalanan semasa Hari Bebas Kenderaan dan hari-hari biasa; oleh itu, inisiatif Hari Bebas Kenderaan UTM tidak mengurangkan jarak perjalanan di kampus. Hasil kajian ini dapat memberi manfaat kepada program inisiatif Hari Bebas Kenderaan UTM. Akhir sekali, kajian ini mengesyorkan cadangan yang boleh meningkatkan kejayaan inisiatif Hari Bebas Kenderaan UTM dan aspek-aspek yang meningkatkan metodologi penilaian kesan Hari Bebas Kenderaan mengikut jarak perjalanan.

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LIST OF ABBREVIATIONS

CFD	Car-Free Day
CGSS	Center of Global Sustainability Studies
CO ₂	Carbon Dioxide
GMD	Geodetic Datum of Malaysia
GIS	Geographic Information System
GIS-T	Geographic Information System for Transportation
OD	Origin-Destination
SCP	Sustainability Campus Programs
SPSS	Statistical Package for Social Science
UKM	Universiti Kebangsaan Malaysia
UM	Universiti Malaya
USM	Universiti Sains Malaysia
UTM	Universiti Teknologi Malaysia
UTMCS	Universiti Teknologi Malaysia Campus Sustainability
UUM	Universiti Utara Malaysia

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

In many parts of the world, many public and private educational institutions introduced variety initiatives to improve environment and achieve campus sustainability (Brinkhurst *et al.*, 2011). Generally, campus sustainability is considered as an issue of global concern as results of the realization of developmental projects, campus community activities and operations taking place on university campuses have impacts on the environment (Alshuwaikhat and Abubakar, 2008).

Beginning with the Stockholm Declaration of 1972, there has been a growing number of sustainability declarations that are pertinent to higher educational institutions (Wright, 2002). Thus, many universities took environmental concerns into consideration and signed these sustainability declarations to show their commitment to environmental sustainability. Talloires Declaration of 1990 is one of these sustainability declarations

and is described as “a ten-point action plan for incorporating sustainability and environmental literacy in teaching, research, operations and outreach at colleges and universities” (Declaration, 1990). In 2003, the Talloires Declaration was signed by 300 universities in 47 countries across five continents (Shriberg and Tallent, 2003).

Variety approaches were used to implement sustainability programs and reduce carbon emissions, as many cities around the world have embraced car-free days and such events have been reported from Seoul to Surabaya, London to Bogota and from Cape Town to Brasilia (Badiozamani, 2003). At the moment, the Car-Free Days are being held to reduce traffic induced emissions and promote a shift from car dependency to alternative sustainable modes of transportations; although the first Car-Free Day program was held in Switzerland due to oil crisis at that time (Anwar *et al.*, 2009); however, only few cities have succeeded in a complete ban on private vehicles on a working day (Politis *et al.*, 2012).

University campuses are considered as unique communities due to different people with different backgrounds, lifestyles and attitudes that came together for study and work (Balsas, 2003). For that reason, decision makers of universities are required to be proactive in encouraging campus sustainability through setting environmental rules and regulations and using variety approaches for the assessment and improvement of activities and operations taking place in universities (Alshuwaikhat and Abubakar, 2008). Thus, introducing and adopting a Car-Free Day initiative on campuses were addressed for promotion of alternative modes of transportation (Politis *et al.*, 2012). Some universities supported the world Car-Free Days on 22 September, whereas others introduced their own environmental regulations to limit unnecessary car-use on campuses (Miralles-Guasch and Domene, 2010; Politis *et al.*, 2012).

The considerable differences among educational institutions arise from using different approaches for achieving campus sustainability (Brinkhurst *et al.*, 2011). For instance, some universities in Malaysia such as Universiti Teknologi Malaysia (UTM) launched a sustainable campus program for the achievement of reduction of carbon emissions by initiating Car-Free Days projects in December, 2016 (UTMCS, 2017). Whereas Universiti Kebangsaan Malaysia (UKM) officially launched Sustainability Campus Programs (SCP) aimed at conducting research in the field of sustainability and carrying out campus sustainability activities such as Eco Green Campus Challenge Program (Fadzil *et al.*, 2012).

UTM is one of the universities which concerned about campus sustainability based on the vision of the realization sustainable lifestyle on the campus in terms of transportation, waste management, air, water and energy in order to preserve the current resources for future generation. To ensure reduction of carbon emissions and increase the level of awareness among campus community towards sustainability, UTM proposed Car-Free Day plans. The Car-Free Days were officially launched in December, 2016 and supposed to be continued until December, 2017 on a monthly basis.

Assessing the successfulness of the UTM Car-Free Day, UTM Campus Sustainability (UTMCS) has been conducting many online questionnaires since December 2016. The main objective of the survey is to assess the awareness of the campus community towards the Car-Free Day initiative (UTMCS, 2017). Additionally, there is also need to be measured the successfulness of this Car-Free Day initiative by looking at whether the initiative met its requirements within the specified timeframe and cost. Moreover, it is also needed to be assessed whether the initiative achieved its objectives. Baeten (2002) suggested that 5 conditions to be fulfilled in order to have a successful Car-Free Day. The first condition is that the actors of the Car-Free Day event should be motivated to organize the event; secondly, the different actors that can be involved have to be mobilized; thirdly, the choice of Car-Free areas must be logical,

practical and realistic in terms of awareness raising objectives; fourthly, much attention has to be paid to an efficient information and communication strategy; and fifthly, programming of activities are necessary to organize activities in order to entice people to visit the Car-Free area.

Car-Free Days can be further assessed using Geographic Information System (GIS) techniques. GIS offers a tool that is designed to work with geospatial data and it contains database system for storing, manipulating, analyzing, querying, retrieving and displaying data in the form of maps, charts, tables. GIS has significant contributions as decision support tool for the assessment of problems. For the past decades, many studies were conducted using GIS technology for road network analysis, sustainable mode of transport using GIS and analyzing accessibility (Ford *et al.*, 2015). In early decades, GIS technology supported transportation planning by analysis of spatial distributions and patterns such as solving the fastest and shortest paths between two locations on a road network (O'Sullivan *et al.*, 2000). It was comprehensively developed models of modes of transportation and accessibility and focused on measurements of time and distance for the assessment of transportation sustainability (Ford *et al.*, 2015). Recent years, improvements of GIS software systems were performed and tools for the basic GIS functions were developed to enhance the capacity and functionality of GIS software as Benenson *et al.* (2011) developed an ArcGIS-based toolkit to compute travel time and service locations.

Therefore, the study uses distance measurement methods in GIS that best meets the purpose of this study. Since travel distances are associated with vehicle's carbon emissions, this study focuses on the impact of the UTM Car-Free Days on travel distances using distance measurement method by measuring travel distances from residential addresses of research population to their pertinent parking lots in order to determine whether the Car-Free Day initiative reduces the distances travelled on the campus.

1.2 Statement of Research Problem

Caring for environmental resources and encouraging for sustainability is a vital response of the world society in order to make sure environmental survival and well-being (Bernheim, 2003). Recently, university campuses are required to improve and protect the environment to achieve campus sustainability (Alshuwaikhat and Abubakar, 2008). Over the past decades, many universities have taken environmental sustainability into consideration (Simkins and Nolan, 2004), and some higher educational institutions called for the need of Green Campus concept to be practiced and universities interpreted and used the green agenda in different terms, some universities used green building, green campus and high performance buildings. The methods that were used to implement the green agenda are also different from one educational institution to another (Alshuwaikhat and Abubakar, 2008).

There is a need to practice campus sustainability that covers all activities including transportation and operations taking place on the UTM campus. There are many factors that can be attributed that the UTM campus community tend to use vehicles on the campus: (a) the campus occupies large areas and campus facilities are scattered around the campus that make the campus community more necessary to travel by vehicle, (b) earth surface of the campus is not flat that makes the campus community challenge to walk or bicycle, and (c) weather conditions hinder walking and bicycling on the campus.

Although vehicles have positive effects on speed, convenience and accessibility to remote areas, the overuse of vehicles has negative impacts on environmental quality. Moreover, the increase of vehicles on the campus creates air and noise pollutions (Nieuwenhuijsen and Khreis, 2016). As a result of unsustainable modes of transportations, UTM launched Car-Free Day initiative to encourage the campus

community to change using vehicles to sustainable lifestyle modes of transportation such as walking or bicycling.

Many studies were conducted, in a greater extent, about campus sustainability using different techniques such as questionnaires (Isa, 2016), behavioral observation and visual study (Abd-Razak *et al.*, 2011). There is lack of published studies that used GIS analysis techniques for the assessment of Car-Free Day initiatives. However, many studies were conducted that assessed Car-Free Days using different assessment methods such as interview survey by face-to-face methods (Anwar *et al.*, 2009), survey questionnaire (Politis *et al.*, 2012), qualitative research methods including literature review and observations (Møller Thomsen, 2016).

On the other hand, many studies were also conducted that used distance measurements as a GIS analysis technique for the assessment of accessibility to facility areas (Ludwick *et al.*, 2009; Pearson *et al.*, 2017) and finding optimal path (Alivand *et al.*, 2008). Gutiérrez and García-Palomares (2008) investigated the impact of distance measurement on the calculation of transport service areas and considering factors that affect the overestimation of distance measurement methods such as street-network design, the density of bus stops and barriers, whereas Nicholl *et al.* (2007) utilized straight-line distance measurement techniques to investigate the relationship between the mortality rate and distance to a health center. Furthermore, there are also other studies that compared different types of distance measurement methods such as Euclidean distance, Manhattan distance, Minkowski distance and road network distance and found that strong positive correlations among distance metrics (Apparicio *et al.*, 2008; Boscoe *et al.*, 2012; Shahid *et al.*, 2009). All these studies used distance measuring techniques, and measuring distance was an integral part for the assessment of different aspects in real life situations.

Therefore, the selection of an appropriate GIS analysis technique for assessing the current UTM Car-Free Day is important. However, in this study, it is used distance measurement methods for the assessment of Car-Free Days as distance measurement methods provide an accurate and more realistic measurement on travel distances and also help for modelling actual travel patterns in order to indentify if there are any differences in travel distances during Car-Free Days and normal days.

Thus, the need of GIS assessment methods for the evaluation of Car-Free Days and the above-mentioned pressures on the university environmental goals for achieving overall balanced ecosystem of green campus targets necessitate this study to be conducted in order to be further assessed the current UTM Car-Free Day initiative using distance measurement methods in GIS.

1.3 Aim of the Study

The overall aim of this study is to utilize distance measurement methods in GIS for the assessment of the impact of Car-Free Days on travel distance on UTM main campus.

1.4 Objectives of the Study

To achieve the aim of the study, the study focuses on the following objectives:

1. To review Car-Free Days assessment methods and distance measurement methods in GIS.
2. To model travel patterns using distance measurement methods in GIS.
3. To evaluate travel distances covered by vehicles during Car-Free Days and normal days.

1.5 Research Questions

This study focuses on three objectives. In order to achieve the overall aim of the study, the study is guided by research questions as shown in the Table 1.1. The research questions are a core fundamental for this study and determine literature review, methodology, analysis and recommendations as well.

Table 1.1: Research Questions

No.	Objectives	No.	Research Questions
1.	To review Car-Free Days assessment methods and distance measurement methods in GIS.	1.	What are different types of distance measurement methods in GIS?
		2.	What are appropriate assessment methods of Car-Free Days?
2.	To model travel patterns of Car-Free Days and normal days using distance measurement methods in GIS.	1.	How can travel patterns be modelled using shortest path network and actual travel route measurements?
		2.	What are the roads with the highest traffic flow on the campus?
3.	To evaluate travel distances covered by vehicles during Car-Free Days and normal days.	1.	Are there any significant differences between travel distances between Car-Free Days and normal days?
		2.	Are there any significant relationships between travel distances using shortest path network and actual travel route measurements?

1.6 Scope of the Study

The study focuses on an assessment of Car-Free Days on UTM campus, Johor, Malaysia using distance measurement methods in GIS by measuring travel distance from residential addresses of the research participants to their usual parking lots on UTM campus. Moreover, the study also compares travel distances during Car-Free Days and normal days, in this study, it is not assessed carbon emissions produced by vehicles

during Car-Free Days and normal days. The study uses existing data that are road network datasets and related spatial data downloaded from OpenStreetMaps, and primary data obtained by conducting questionnaire. Both ArcGIS Desktop and IBM SPSS Statistics are utilized for the analyses of the study. However, the study is conducted within limited time frame from February, 2017 to August, 2017.

1.6.1 Study Area

The study takes UTM campus as a study area; UTM has two campuses in Peninsular Malaysia: One branch is located in Kuala Lumpur, the capital of the country and the main campus is located in Skudai, Johor Bahru, Johor where the study is conducted. UTM is a research university with a total population of 20,654 both academic staffs and students (UTM, 2016).

The main UTM campus was divided into different zones that are scattered around the campus. The inner circle of the campus which is known as Lingkaran Ilmu (knowledge circle) contains the main buildings of the university that can easily accessible and promotes pedestrianism; it consists of faculties, administration buildings, main library, mosque and main halls as shown in Figure 1.1. Hostels, staff residences, food arcades and recreational areas are located outside of the inner circle. Since different zones of the campus are occupying a total areas of 1,222 hectares (SPS, 2016), different modes of transportation such as bicycles, personal cars, motorbikes and campus shuttles are used for the accessibility.

In terms of land use, the main UTM campus consists of the academic and administrative zone (14.61%), student residential zone which covers huge percentage of the campus' land use and estimated approximately (25.58%), sports and recreational zone (14.15%), commercial development zone (2.42%), staff residential zone (6.08%) and technology park (15.49%). The total green area is 850 acres that consist of the forest reserve, fruit farm, artificial and natural landscape, rivers and lakes covering (21.67%) of the total area. Generally, the whole campus augments the Green Campus concepts by enhancing healthy living of the campus community entirely as a mix of social and environmental factors (Zen *et al.*, 2014).

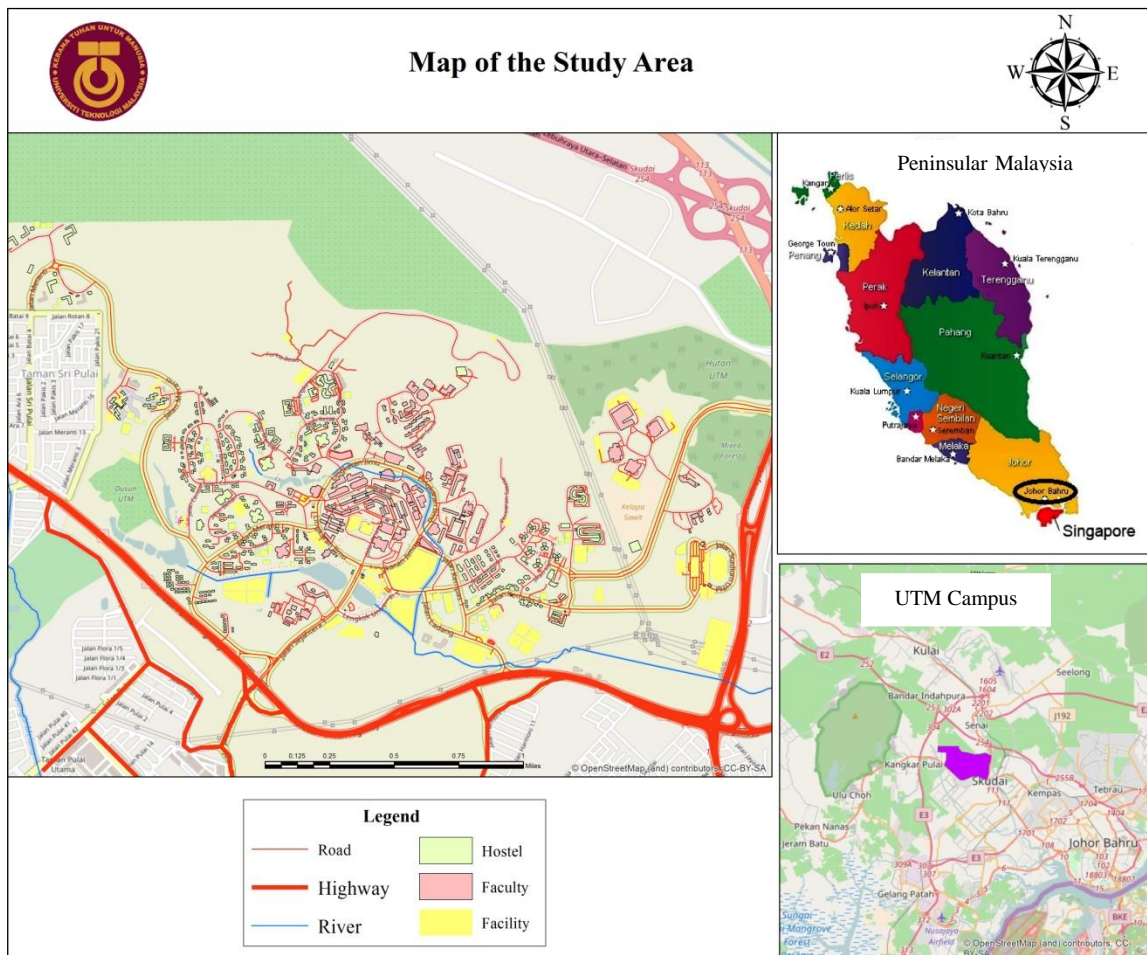


Figure 1.1: Map of the Study Area (OpenStreetMaps, 2017)

1.7 Assumption of the Study

The study has an initial assumption that the Car-Free Days reduce the travel distances from origins to parking lots and improve sustainable modes of transportations as walking, bicycling, campus shuttles, hybrid-car and buggy cars, whereas normal days increase the travel distances and also increase car-induced emissions by reducing health lifestyle sustainable modes of transportations as illustrated in Figure 1.2. Therefore, the study utilizes ArcGIS software tools to measure travel distances and model travel patterns. Moreover, dependent *t*-test for paired samples is used to compare travel distances during Car-Free Days and normal days and verify whether the Car-Free Day initiative reduces travel distances on UTM campus.

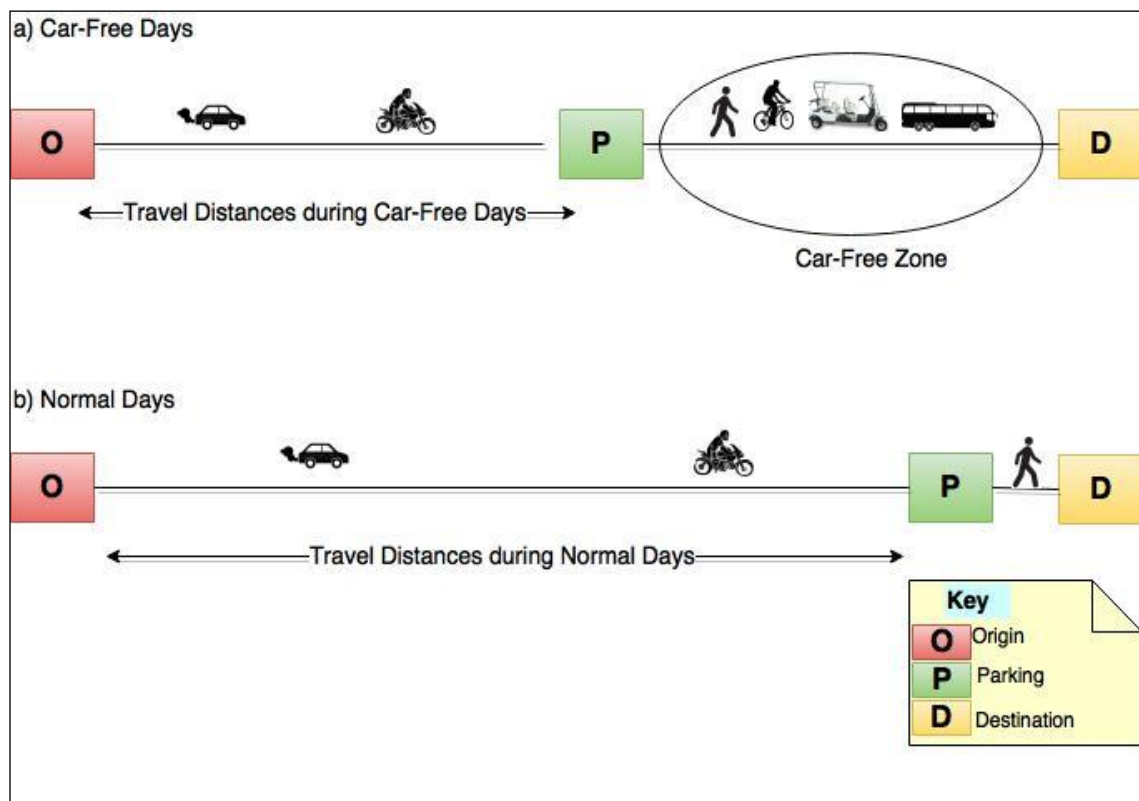


Figure 1.2: Assumption of the Study

1.8 Significant of the Study

The findings of the study greatly contribute to the basic understanding of distance measurement techniques in GIS for the assessment of Car-Free Days on university campuses. The study is also useful for the growth of studies about Car-Free Days and campus sustainability. Moreover, this study is expected to contribute to recommendations and suggestions about the assessment and implementations of Car-Free Day initiative on the campus that are useful to the stakeholders such as UTM Campus Sustainability (UTMCS) office and also literature for the ongoing research projects about Car-Free Day initiatives.

1.9 Organization of Chapters

Chapter 1: Introduction

This chapter is intended to introduce the background of the study that gives general overview of the study. The chapter also elaborates the problem and justifies the reasons that necessitate for conducting the study. Similarly, the chapter describes aim, objectives and research questions that guide the whole study.

Chapter 2: Literature Review

This chapter surveys books, theses and dissertations, scholarly articles and other resources that are relevant to Car-Free Days, assessment methods for the Car-Free Day

initiatives, campus sustainability, low carbon campus, campus community perceptions in relation to sustainable mode of transportations and different distance measurement techniques in GIS for the assessment of Car-Free Day initiative.

Chapter 3: Methodology

In this chapter, it is concentrated on methods for data collection, data sources, workflow of the study and distance measurement techniques for the assessment of the study using shortest path network and measuring actual travel routes of the respondents. The study also conducts correlation test to determine the relationship between shortest path network and actual travel route measurements and utilizes dependent *t*-test for paired samples to compare travel distances of Car-Free Days and normal days.

Chapter 4: Results and Analyses

This chapter is intended to analyze, interpret and report the results of the study based on the overall aim and the specific objectives of the study. The study presents the results in the form of maps, charts and tables. The main results of the study are traffic flow maps, correlation of shortest path network and actual travel route measurement, comparing travel distances and level of awareness of campus community towards Car-Free Days.

Chapter 5: Conclusion and Recommendations

This chapter draws a conclusion reflecting the achieved objectives of the study. The chapter also contributes to recommendations and suggestions about Car-Free Day plans and assessment methods for the initiative. Moreover, the chapter also sheds light on the limitations of this study that are recommended for further study.

- iv. Since OD Cost Matrix of ArcGIS software measures the least cost road for multiple origins and destinations without mapping a route geometry, it would be time saving, if a simple tool were developed to find shortest path for multiple origins and destinations, and generate a route geometry.
- v. Assessing carbon emissions produced by vehicles was beyond the scope of this study, therefore, comparing carbon emissions emitted by vehicle types during Car-Free Days and normal days would indicate whether the Car-Free Days reduce vehicle emissions or not.

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